

PARTICULATE IMPACTS ON VISIBILITY AT THE GRAND CANYON FROM NORTHWESTERN MEXICO

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ABSTRACT

Project MOHAVE was a large study to investigate the causes of visibility impairment in the Grand Canyon National Park region. An episode with regionally elevated sulfate gave the highest concentrations of sulfate measured at Meadview just west of the Grand Canyon on September 1 and 2, 1992. The elevated sulfate concentrations extended south into northwestern Mexico. Based on wind profiler data, emissions from the power plant in the vicinity of Meadview, MPP, could not have been responsible for the regionally observed sulfur oxides. A CMB model developed during Project MOHAVE was used to apportion sulfur oxides at Meadview and other sampling sites throughout the study region for August 31 - September 2, 1992. The results indicate that the contribution of MPP to sulfate at Meadview was typical. However, transport of SO_x from northwestern Mexico was elevated throughout much of the region during this time period. This led to the large increase in sulfate concentrations at Meadview on September 1 and 2. In addition to this major episode, the results obtained with the CMB model indicate that particulate emissions originating from northwestern Mexico are frequently present during the summer at the Grand Canyon. These results indicate that Mexico can be a significant source of visibility reducing particles at the Grand Canyon.

BACKGROUND AND METHODS USED

Project MOHAVE¹ was a joint partnership research program between the U.S. Environmental Protection Agency, the National Park Service and Southern California Edison. An objective of the program was to establish the relative contribution of emissions from the Mohave Power Project, MPP, to visibility degradation in the Grand Canyon region.

Chemical mass balance receptor based apportionment techniques have been used to estimate the point sources and regional contributors to SO_x (SO_2 plus particulate sulfate) and fine particulate sulfate present in the study region^{2,3}. Source profiles of SO_x from the four coal-fired generating station closest to the Grand Canyon National Park and from the various regional sources which can impact the Grand Canyon have been developed using spherical aluminosilicate (SAS) particles present in coal-fired power plant emissions^{3,4}, fine particulate Se, As, Pb, and Br, and light absorption by fine particles^{3,4}. These source profiles allow the CMB discrimination among the various point and regional sources of SO_x in the southwestern United States^{2,3}.

Details of the identification of the various regional sources and the establishment of the source profiles used in the CMB analysis have been given^{3,4}. The profiles of emissions from the coal-fired generating stations nearest the Grand Canyon [Mohave Power Project (MPP), Navajo Generating Station and Reid Gardner Generating Station were established from both ambient and stack data^{3,4}. The eight regional sources present in the Grand Canyon region during the July-August 1992 summer intensive^{2,3} are summarized below. In addition, the profile of emissions from the coal-fired generating stations in Arizona to the southeast of the Grand Canyon was determined from the ambient data.

The identified regional sources³ and their probable geographical origins^{2,3} include:

SI: Air masses from the San Joaquin Valley, CA area.

LA: Air masses transported from the South Coast Air Basin and the San Diego, CA area.

BC: Air masses for this source region originate from northcentral and northwestern Mexico.

AZ: Characterized by air masses from the area generally south of the Grand Canyon.

SE: Characterized by air masses from southeast of the Grand Canyon and Petrified Forest National Parks.

NW: Days when the sampled air mass at a given site originated from the region north and west of the Grand Canyon established the NW region source profiles. The data were characterized by three distinctly different source regions. These included the profiles for NW1, a region which includes emission from coal-fired power plants (probably in northern Nevada) as evidenced by the elevated SAS/SO₂ ratio, a NW2 local region characterized by a high F_{Total}/SO₂ ratio, and a LV profile in which SAS particles and F_{Total} are absent and which meteorological data suggest includes emissions from the Las Vegas urban area 100 km west of the MV sampling site, Figure 1.

The application of a hybrid CMB model² developed using regional profiles to the Project MOHAVE data accounted for all of the source profile species concentrations and for all of the SO₂ and sulfate. An episode of particular interest occurred at the end of the Project MOHAVE summer intensive. The concentrations of sulfate measured by IMPROVE at Meadview on September 1 and 2, 1992 were the highest concentrations reported at this site in six years of monitoring. During this period, the concentrations of SO₂ at Meadview were also high and about three times the sulfate concentrations. Some investigators have assumed this elevated SO₂ indicated that both SO₂ and sulfate at Meadview were dominated by emissions from the nearby Mohave Power Project, MPP. However, the concentrations of sulfate and SO₂ were also comparably high at all stations south of MPP⁶. We have used a combination of meteorological and CMB analyses to investigate the probable source of this regionally observed SO₂ and sulfate. The meteorological data indicate that MPP could not have been the dominant source of the SO₂ and sulfate present throughout the region during this episode⁶. The results indicate that the contribution of MPP to sulfate at Meadview was no higher than, but comparable to, that seen during the July - August 1992 Project MOHAVE Summer Intensive^{2,3,6}. However, transport of SO₂ from the Baja California CMB source area was elevated throughout the region during this time period. This led to the large increase in sulfate concentrations at Meadview on September 1 and 2.

THE SEPTEMBER 1 & 2 EPISODE

The Hybrid CMB model used to apportion sulfur oxides at Meadview and Hopi Point during the Project MOHAVE Summer Intensive period² was applied to IMPROVE data from the Meadview (MV), Las Vegas Wash (LVW), Cottonwood Cove (CC), Dolan Springs (DS), Essex (ES), Yucca (YU), Parker (PA), Wickenburg (WB) and Painted Desert (PD) sampling sites, Figure 2. These regionally distributed sites were all included in the CMB analysis because the IMPROVE data indicated they were all associated with a marked increase in SO₂ and sulfate on September 1 and 2. For most sites, the sulfate concentrations were higher than those measured during the Project MOHAVE 12 July through 30 August Summer Intensive. The source profiles previously developed as part of the CMB model^{2,3} were used without change. The paradigms previously used for the estimation of SO₂ and sulfate deposition and conversion, and for the regional and Meadview area specific transport times were also used without change². Details of this episode CMB analysis have been given⁶.

The CMB analysis results for sulfur oxide emission sources present in the study region for 2 September are given in Figure 2. As indicated, emissions from both LA and BC were generally present throughout the period at all sites. The impact from BC was greater than from LA for both SO₂ and sulfate. During the episode the highest concentrations of impacts from BC were found at Parker, Essex and Yucca. The highest impacts from LA were found at Essex and Yucca. High impacts for SO₂ (but not sulfate) from MPP were found at Cottonwood Cove, Dolan Springs, Las Vegas Wash and Meadview. Significant impacts from LV were found at Las Vegas Wash and Meadview. The site-to-site and day-to-day changes in sulfate and SO₂ are consistent with a southerly flow resulting in generally decreasing SO₂ concentrations, but an increasing sulfate to SO₂ ratio for the SO₂ from the BC and LA source areas throughout the region. The sulfate impacts at Meadview from all sources for each sampling day are given in Table 1. The highest concentrations of sulfate from MPP were 0.69 µg/m³ at Dolan Spring on 1 September and 0.55 µg/m³ at Meadview on 2 September. All other estimated MPP sulfate impacts were

less than $0.4 \mu\text{g}/\text{m}^3$. In contrast, the highest estimated sulfate impact at Meadview from any source was $1.8 \mu\text{g}/\text{m}^3$ from BC on September 2.

RESULTS FROM THE PROJECT MOHAVE SUMMER INTENSIVE

The results obtained during the episode described above were consistent with the importance of the BC source in the Grand Canyon region during the Project MOHAVE Summer Intensive². These results are illustrated by the data in Figure 3 where are given the total sulfate present at the sampling site at Hopi Point in the Grand Canyon and the sulfate attributed to the BC source region during each day of the Project MOHAVE Summer Intensive. As indicated, sulfate from the BC region were frequently present at Hopi Point. When emissions from this source region were present, they often accounted for the majority of the sulfate. While concentrations as high as the $1.8 \mu\text{g sulfate}/\text{m}^3$ at Meadview on September 2 were not seen at Hopi Point during the summer intensive, concentrations from 0.5 to $1.5 \mu\text{g sulfate}/\text{m}^3$ were frequently seen. The BC region accounted for an average of 42% of the sulfate present at Hopi point during the Project MOHAVE summer intensive². Correlation of the CMB results with measured light extinction at Meadview indicated that light extinction due to anthropogenic emissions from the BC region, per unit of sulfate present from the source, was comparable to that for anthropogenic emissions from most other sources, but only about half that for emissions from the LA source region.⁷ However, the LA source region only accounted for 5% of the sulfate present at Hopi Point.² Thus, combination of the CMB and light extinction data obtained during Project MOHAVE suggest that emissions from northwestern Mexico were the dominant anthropogenic source of visibility impairing particulate material at Hopi Point in the Grand Canyon during Project MOHAVE.

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Table 1. Meadview Sulfate Source Apportionment, 31 August - 2 September 1992, $\mu\text{g}/\text{m}^3$.

Date	MPP	LV	LA	BC	Sulfate Not Fit, % ($\mu\text{g}/\text{m}^3$)
31 Aug	0.3	0.3	0.2	1.1	4.2 (0.1)
1 Sep	0.3	1.4	0.4	0.9	8.4 (0.2)
2 Sep	0.6	0.8	0.6	1.8	14.8 (0.6)

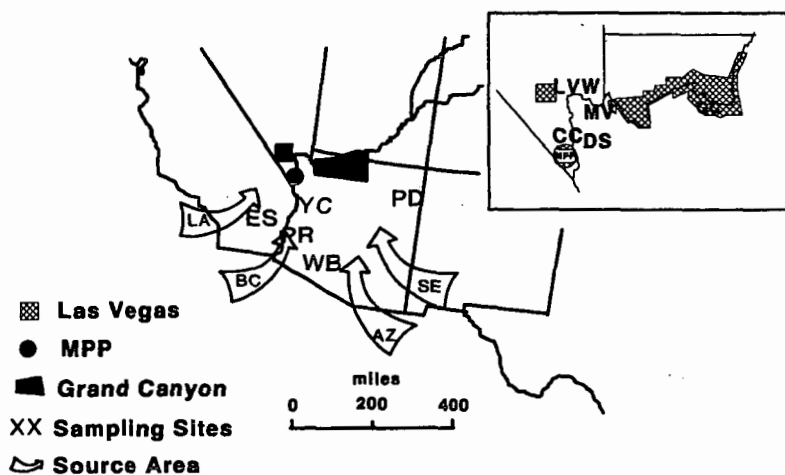


Figure 1. Location of the various sampling sites included in the CMB analysis for 31 August - 2 September 1992, and the expected origins of emissions from the sources included in the analysis; MPP, Las Vegas, LA, BC, AZ and SE.

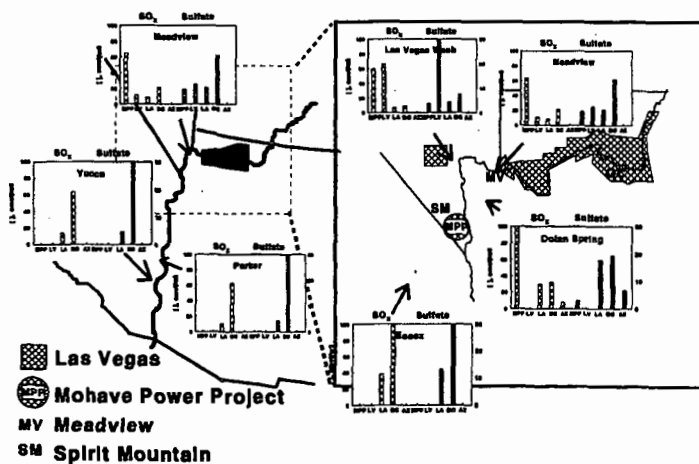


Figure 2. Results of the CMB analysis for SO_2 and sulfate (nmol/m^3) on 2 September 1992 at the sampling sites identified in Figure 1 for the sources identified in Figure 1.

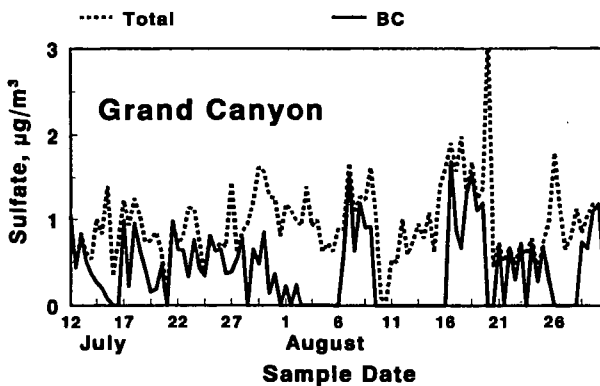


Figure 3. Total and BC sulfate at GC. Northern Mexico is often a major contributor to sulfate at the Grand Canyon.